BNL Review of the sPHENIX Electromagnetic Calorimeter

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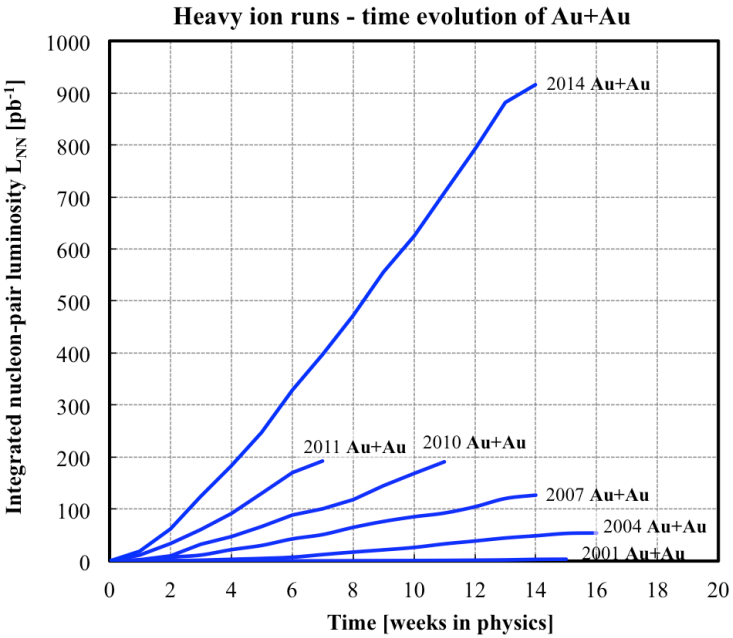
EMCAL Review Agenda

- sPHENIX Overview John Haggerty
- EMCal Conceptual Design Craig Woody
- Performance in Simulation Jin Huang
- Module Production Sean Stoll
- Mechanical Design Chris Cullen
- Sensors, Readout Electronics and Trigger Eric Mannel
- Installation Don Lynch
- Cost and Schedule Ed O'Brien

Fifteen years of RHIC experiments

- RHIC data taking from 2001-2015 has produced large data sets in too many collision energies and species to fit on one page see http://www.rhichome.bnl.gov/RHIC/Runs/ for the full range of collision species and energies
- During that period, accelerator upgrades (particularly stochastic cooling) gave us increased luminosity and extended our physics reach



sPHENIX in a nutshell

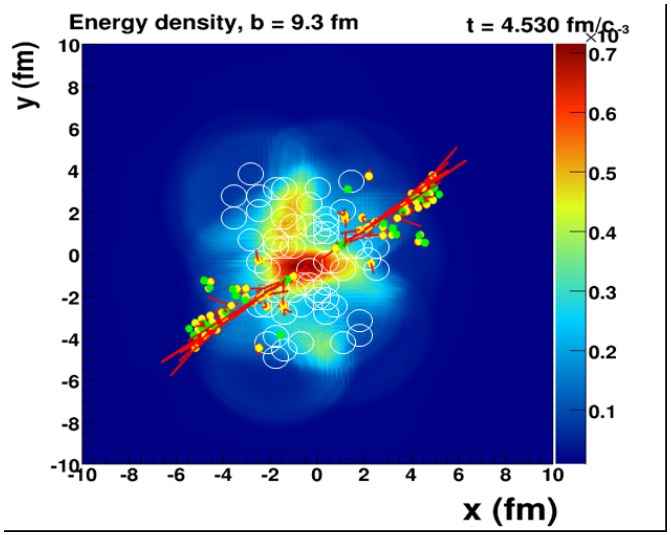
- sPHENIX is a proposal for a new experiment at RHIC capable of measuring
  - jets
  - jet correlations
  - upsilons

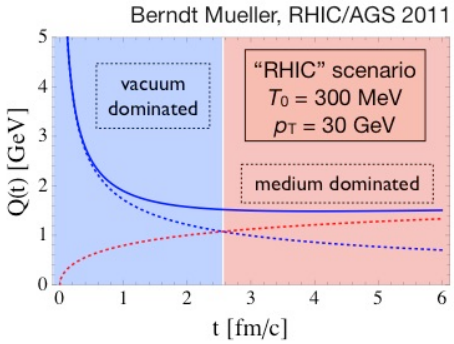
to determine the temperature dependence of transport coefficients of the quark-gluon plasma with a detector comparable to the LHC experiments.

- This experiment enables a program of systematic measurements near the transition temperature at RHIC with a detector capable of acquiring a large sample of events with a high rate data acquisition system from a large acceptance spectrometer with full
  - hadronic calorimetry
  - electromagnetic calorimetry
  - precision tracking

The rationale for jet measurements

- Probing the quark-gluon plasma produced in heavy ion collisions requires a probe that's produced in the medium
- We want to measure the energy loss of quarks traversing the nuclear matter… use jets as a surrogate
- Direct photons and high p_T hadrons in the same experiment





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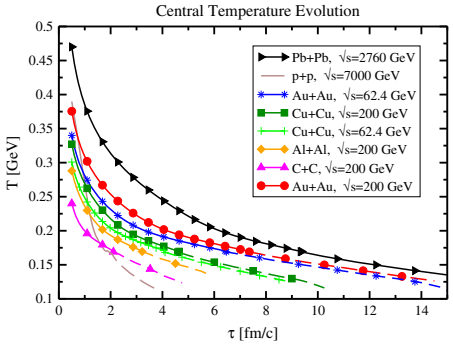

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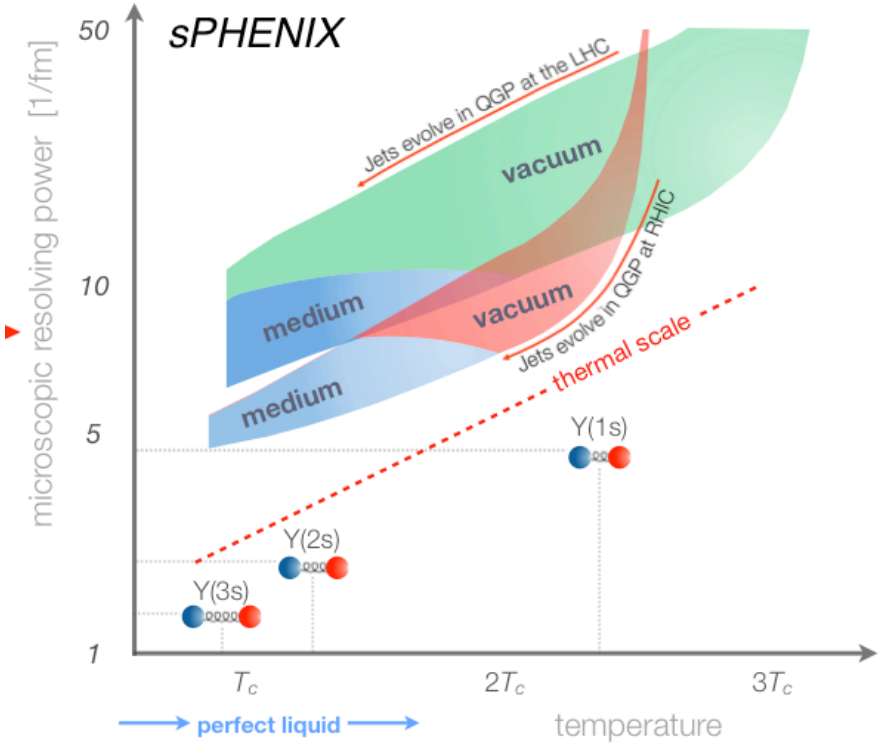
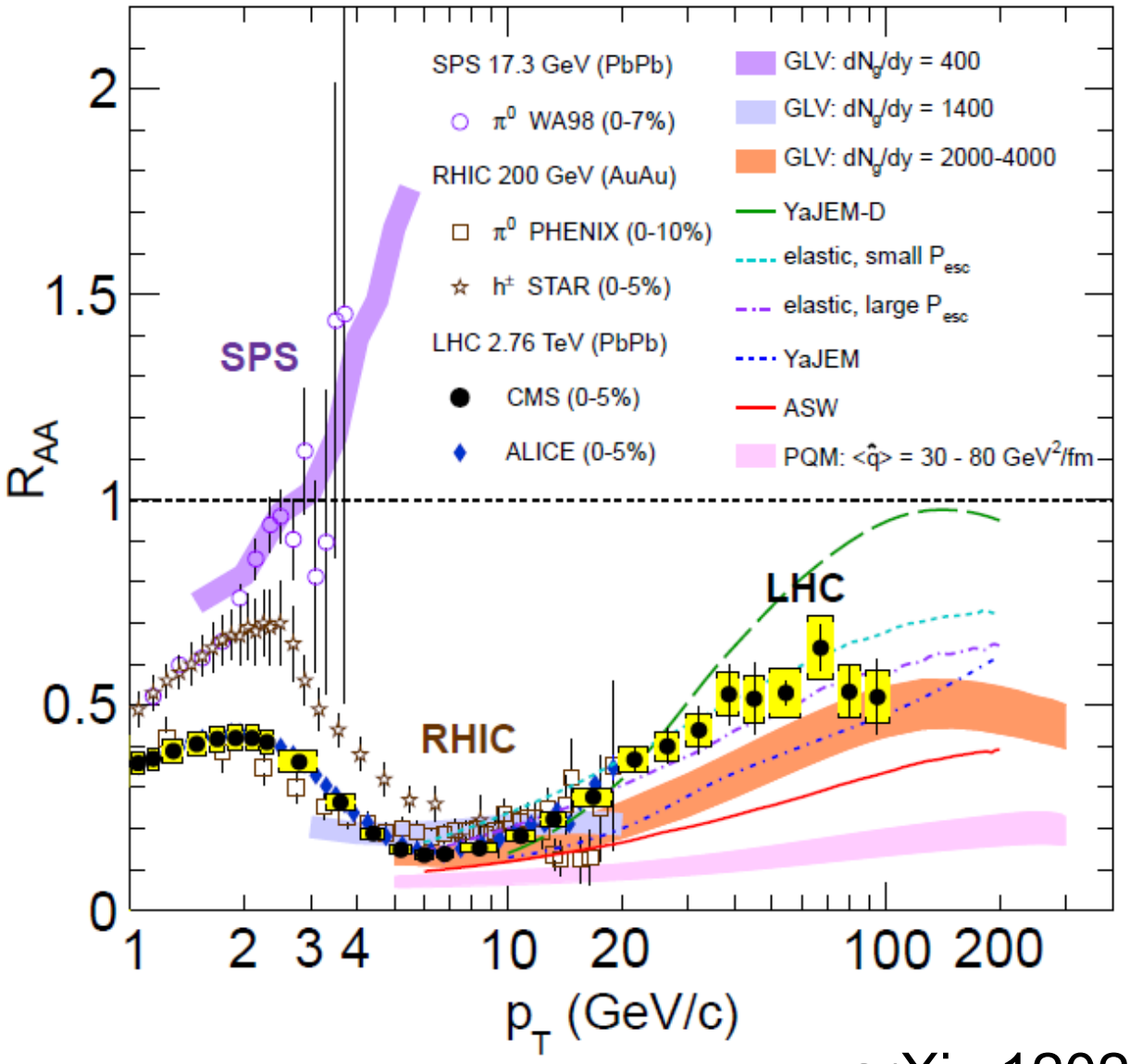
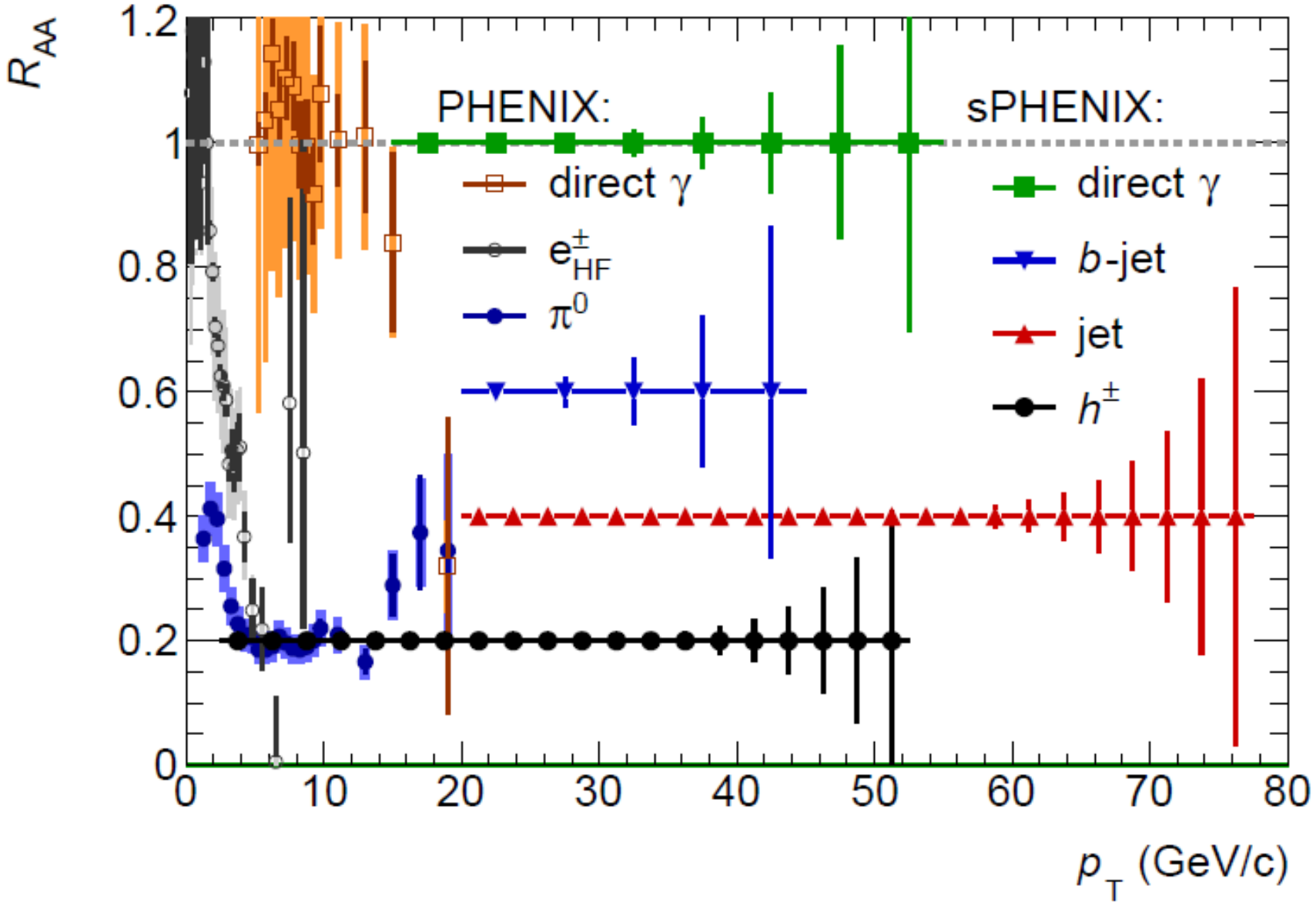




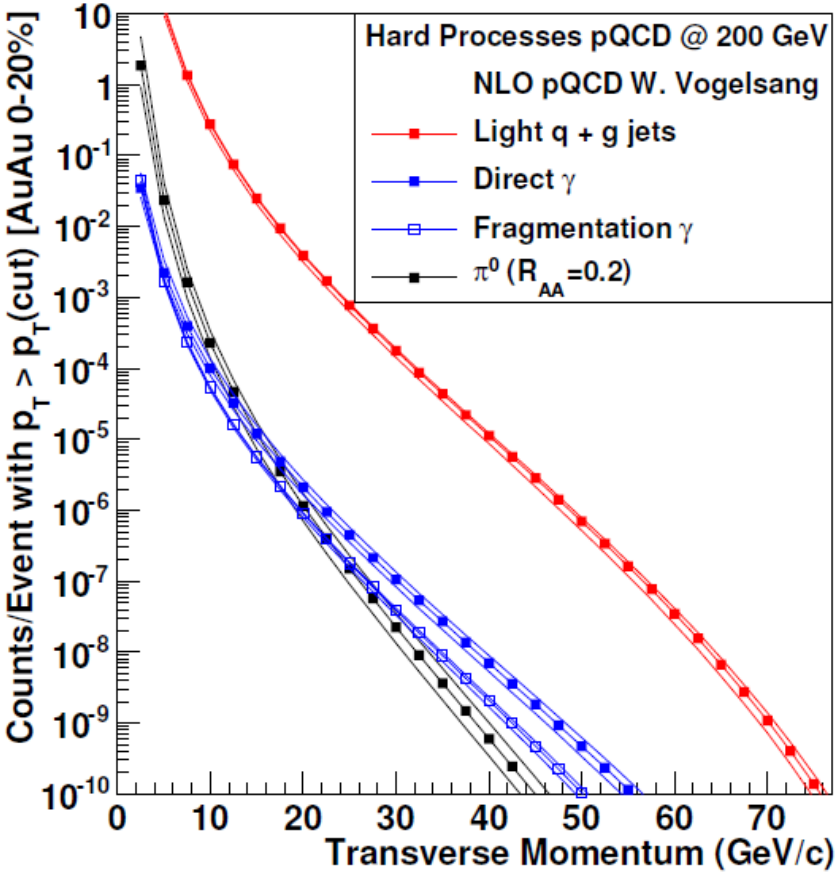
arXiv:1202.2554

PHENIX


R_{AA}
1.2
1
0.8
0.6
0.4
0.2
0
0
10
20
30
40
50
60
70
80
p_T (GeV/c)
PHENIX:
direct γ
$e^{\pm}_{HF}$
π^0
sPHENIX:
direct γ
b-jet
jet
$h^{\pm}$

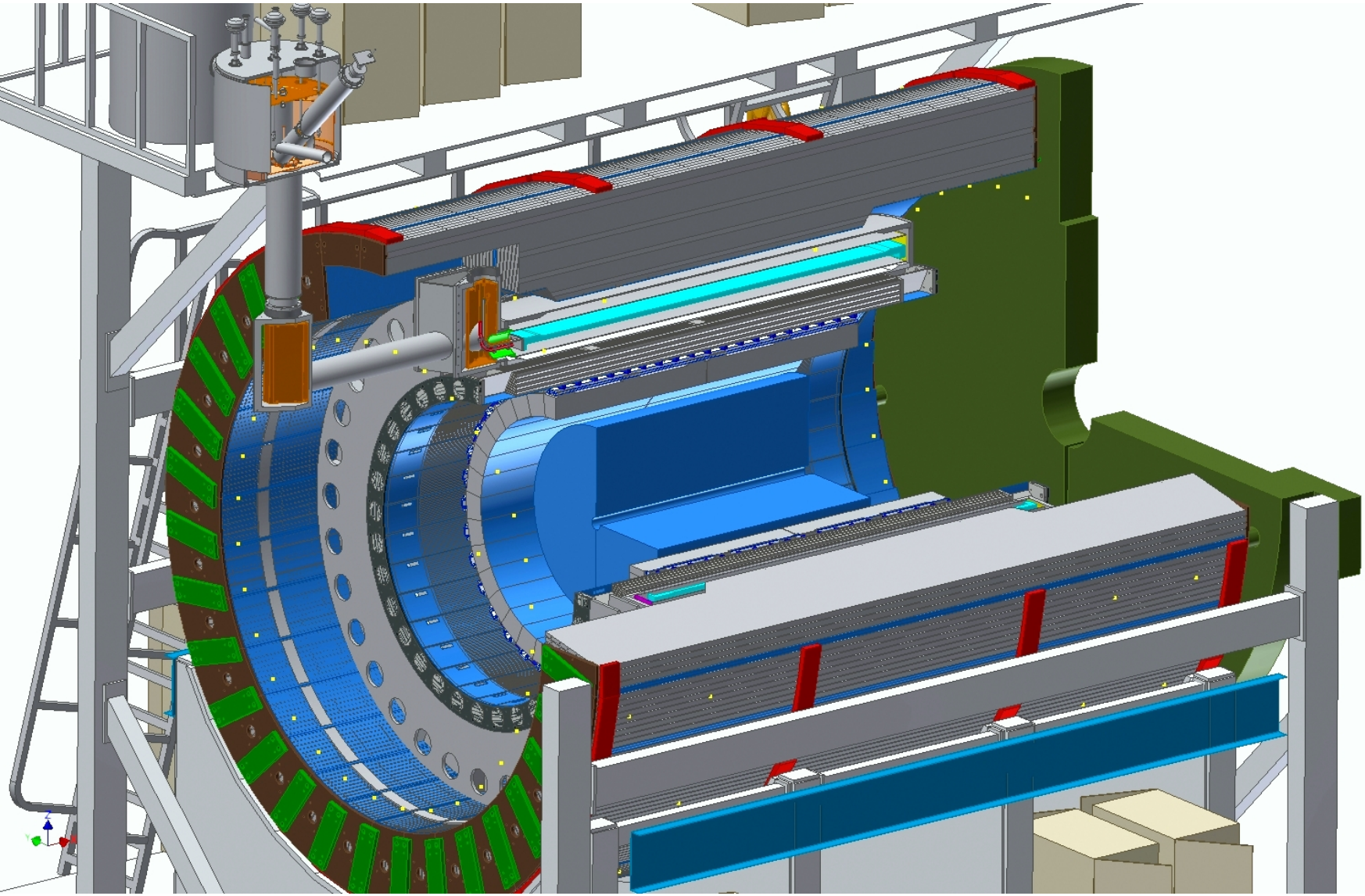
Jets at RHIC

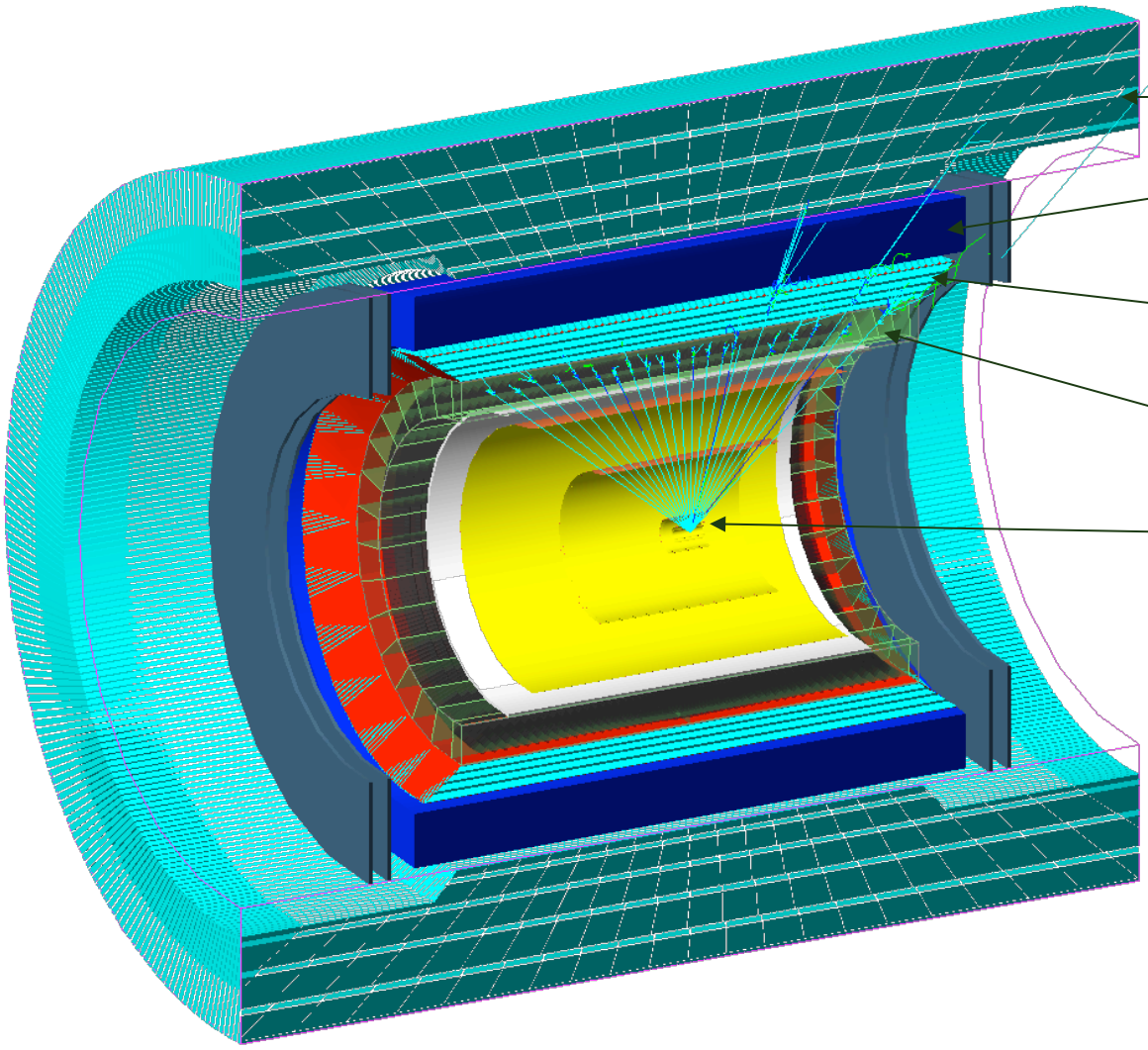
- Design to collect 100 billion minimum bias Au+Au events in one year run
- High statistics jet measurements
  - 10^7 jets above 20 GeV
  - 10^6 jets above 30 GeV
  - 10^4 direct photons above 20 GeV
- Large statistics for γ+jet, b-tagged jets and more



The sPHENIX detector concept

- Uniform acceptance $-1<\eta<1$ and $0<\phi<2\pi$
- Superconducting solenoid enabling high resolution tracking
- Hadronic calorimeter doubling as flux return
- Compact electromagnetic calorimeter to allowing fine segmentation at a small radius
- Solid state photodetectors that work in a magnetic field, have low cost, do not require high voltage
- Common readout electronics in the calorimeters
- 15 kHz recorded in A+A allows for large unbiased MB data sample
- Utilization of infrastructure in an existing experimental hall (cranes, rails, power, network…)





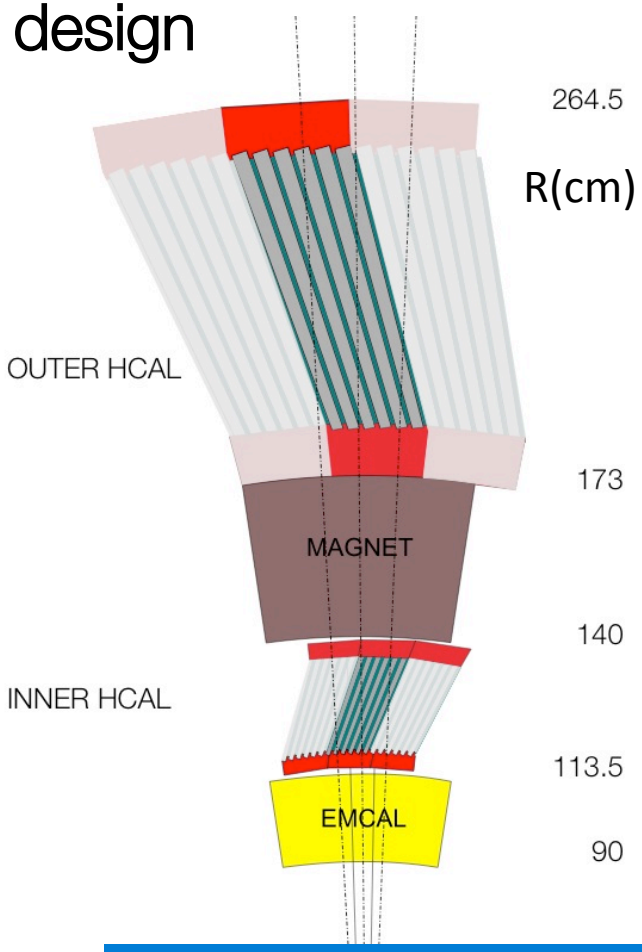
GEANT4

Magnet

- BaBar magnet secured from SLAC after SuperB canceled, arrived at BNL in February 2015
- Well suited to our needs without compromises
  - 1.5 T central field
  - 2.8 m diameter bore
  - 3.8 m long
  - $1.4X_0$ coil+cryostat

Calorimeters reference design

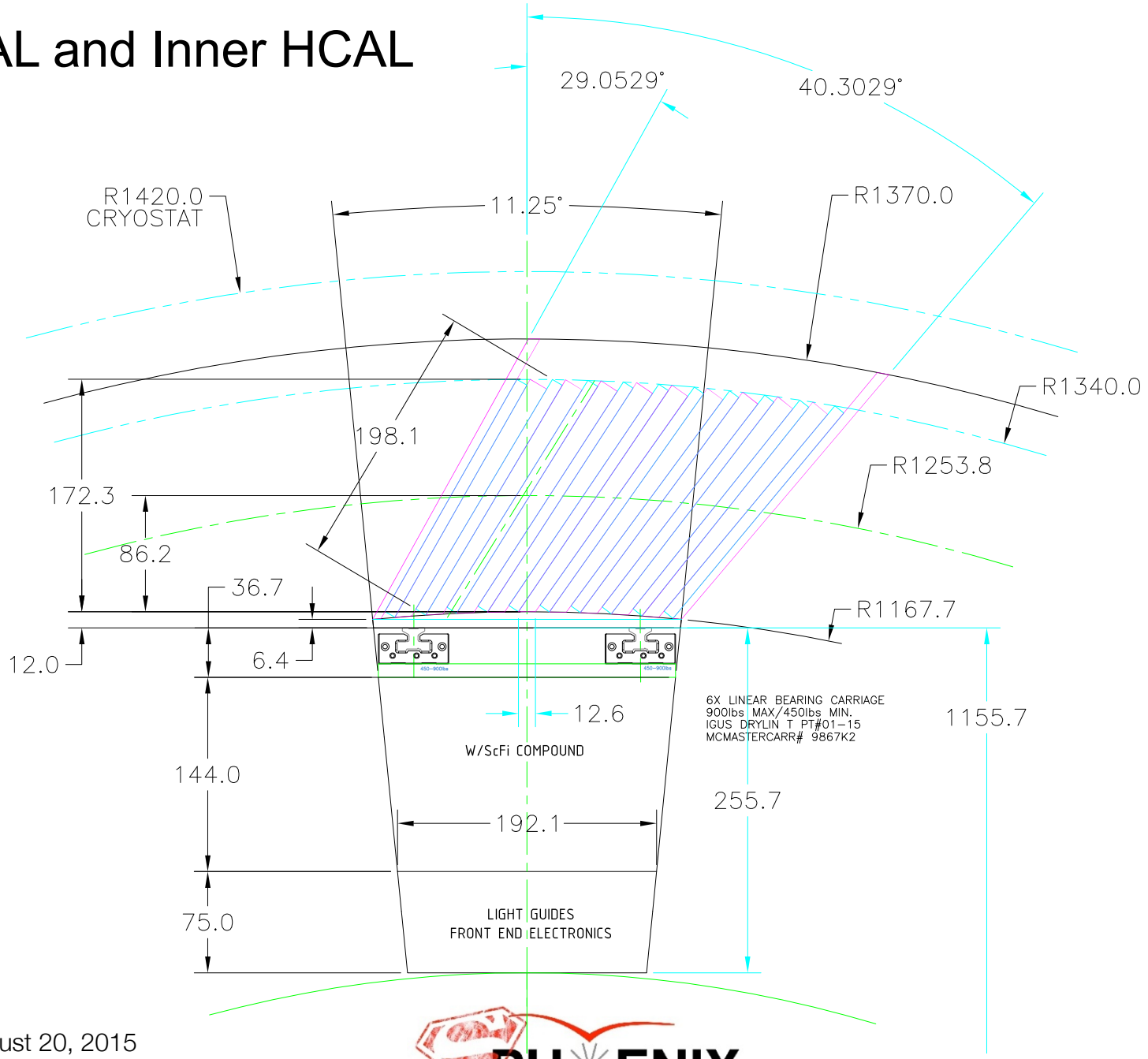
- EMCAL Tungsten-scintillating fiber
  - $\Delta\eta \times \Delta\phi \approx 0.025 \times 0.025$
  - 96 x 256 readout channels
  - EMCal $\sigma_E/E \sim 12\%/\sqrt{E}$ (single particle)
- HCAL steel and scintillating tiles with wavelength shifting fiber
  - 2 longitudinal segments.
  - An Inner HCal inside the solenoid.
  - An Outer HCal outside the solenoid.
  - $\Delta\eta \times \Delta\phi \approx 0.1 \times 0.1$
  - 2 x 24 x 64 readout channels
  - HCal $\sigma_E/E \sim 100\%/\sqrt{E}$ (single particle)
- Readout with solid state photodetectors (silicon photomultipliers)



- Outer HCAL $\approx 3.5\lambda_I$
- Magnet $\approx 0.5\lambda_I$
- Inner HCAL $\approx 1\lambda_I$
- EMCAL $\approx 18X_0 \approx 1\lambda_I$

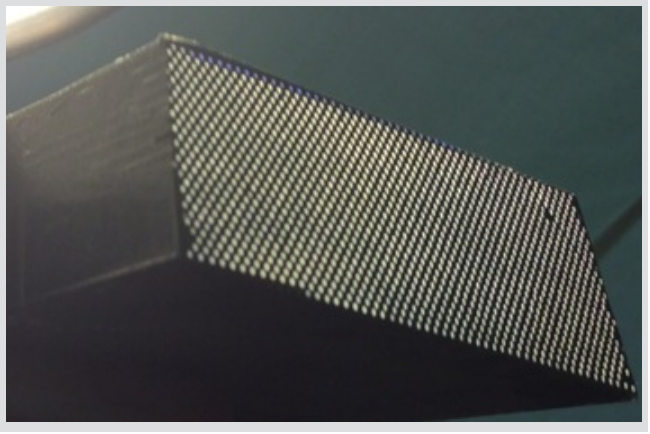
PHENIX

EMCAL and Inner HCAL

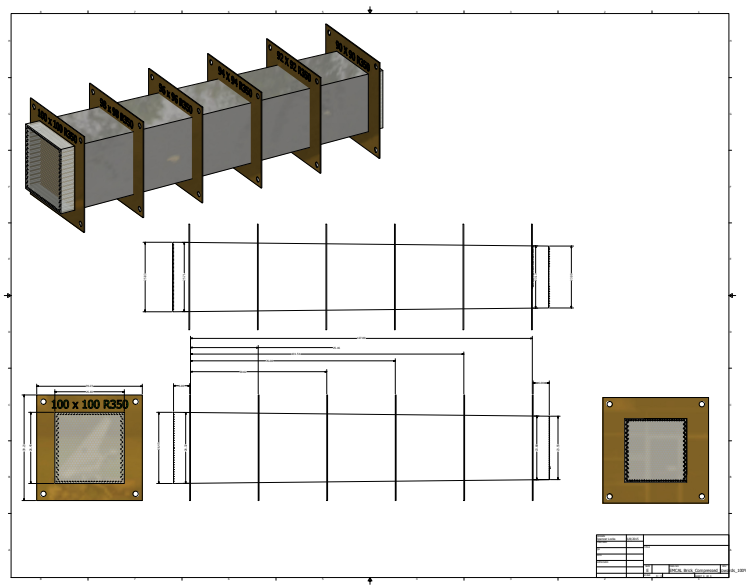


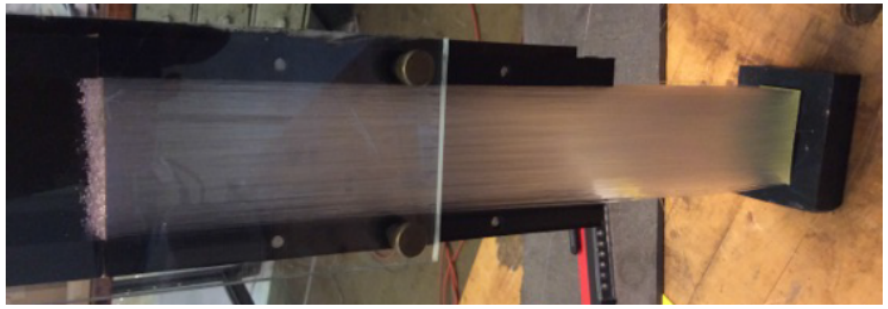
EMCAL

- R&D is going forward at BNL, UIUC, and UCLA on a tungsten-fiber SPACAL developed at UCLA
  - We believe we need 2D projectivity to achieve the e/π separation needed for the Upsilon measurements
- Readout on inner radius of EMCAL with 4 SiPM's per tower
- On-detector electronics limited to preamps, bias control and temperature monitoring
  - Analog signals cabled out of the magnet to waveform digitizers



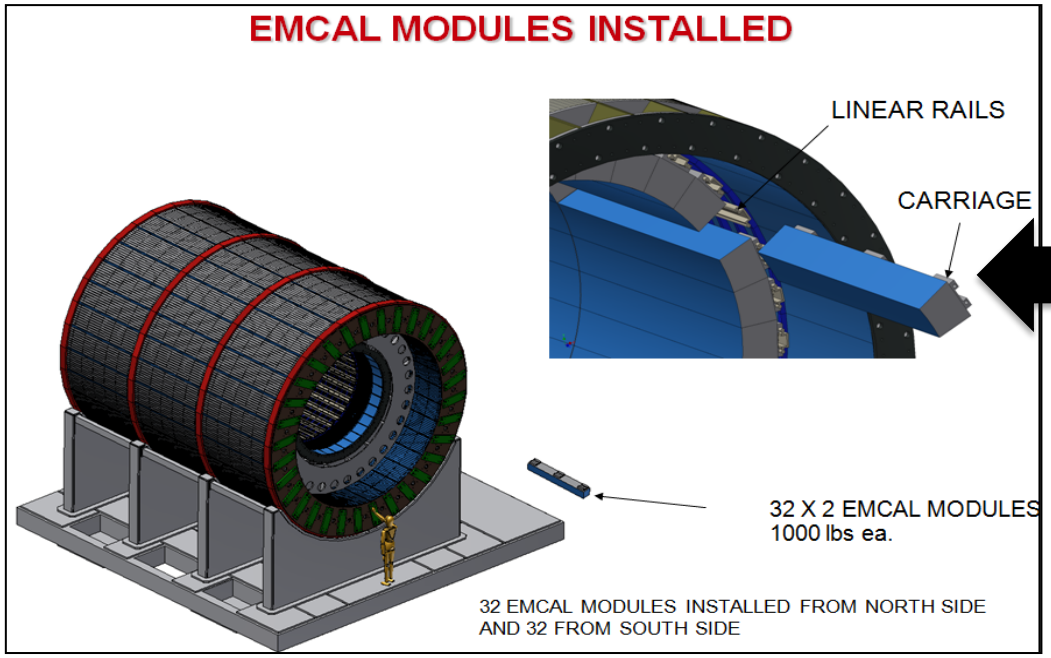
EMCAL module design

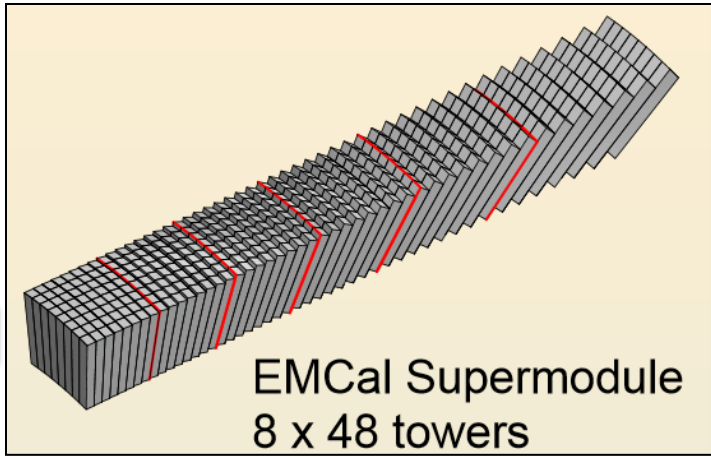




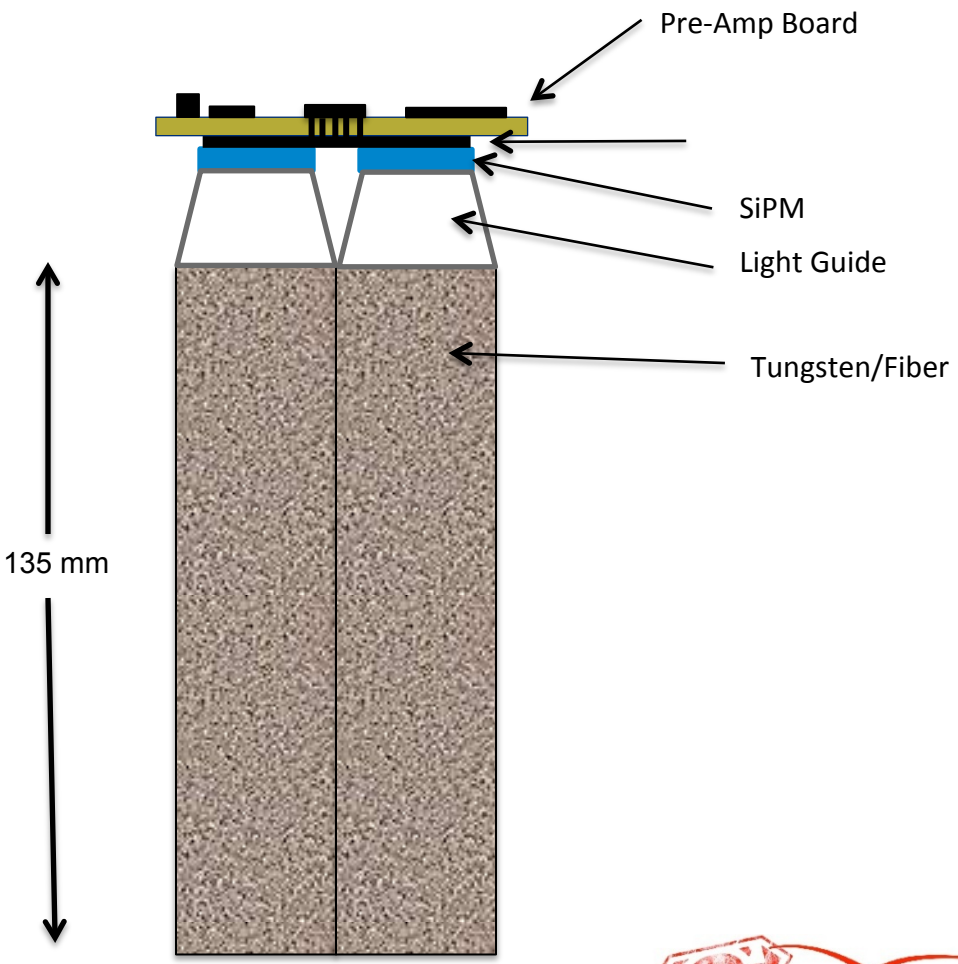
- Fibers threaded through screens
- Filled with tungsten powder and epoxy
- Final density more than half of pure tungsten
- Moliere radius ~2.3 cm

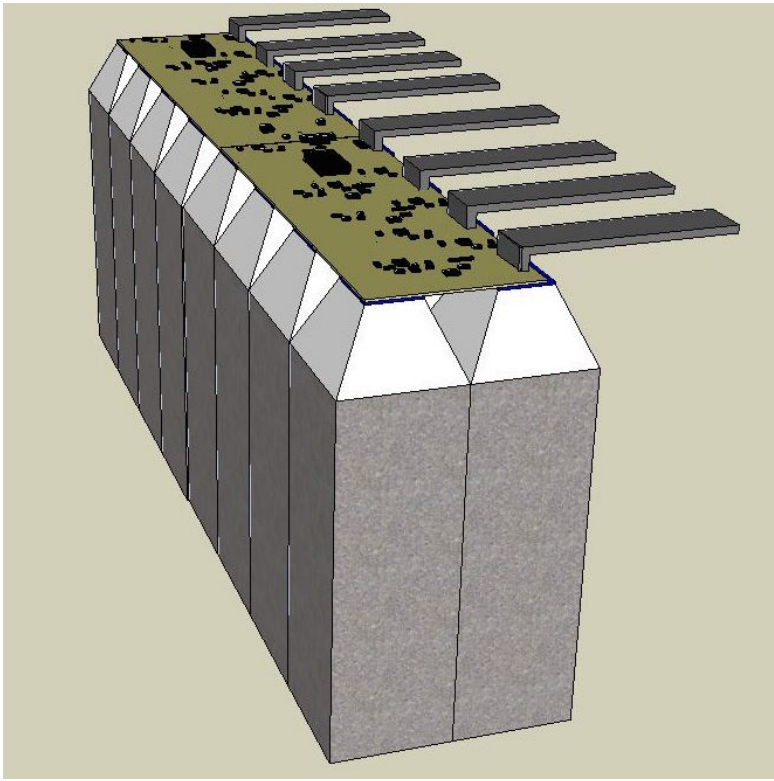
EMCAL sector



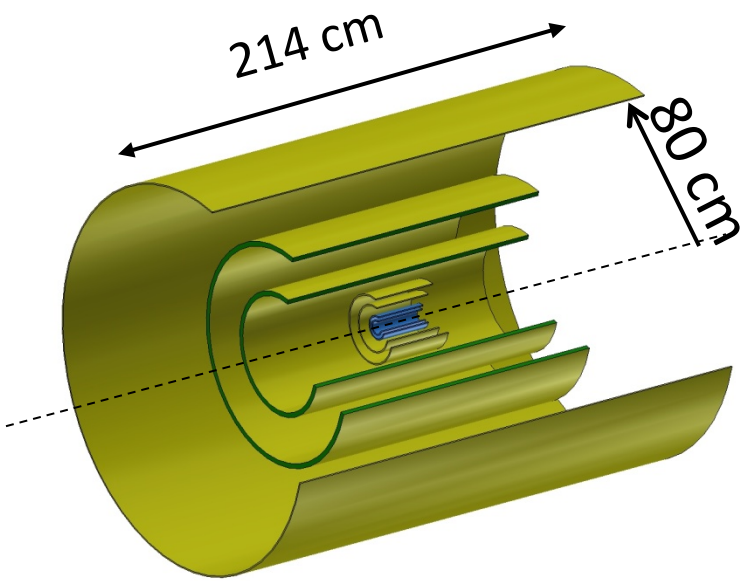


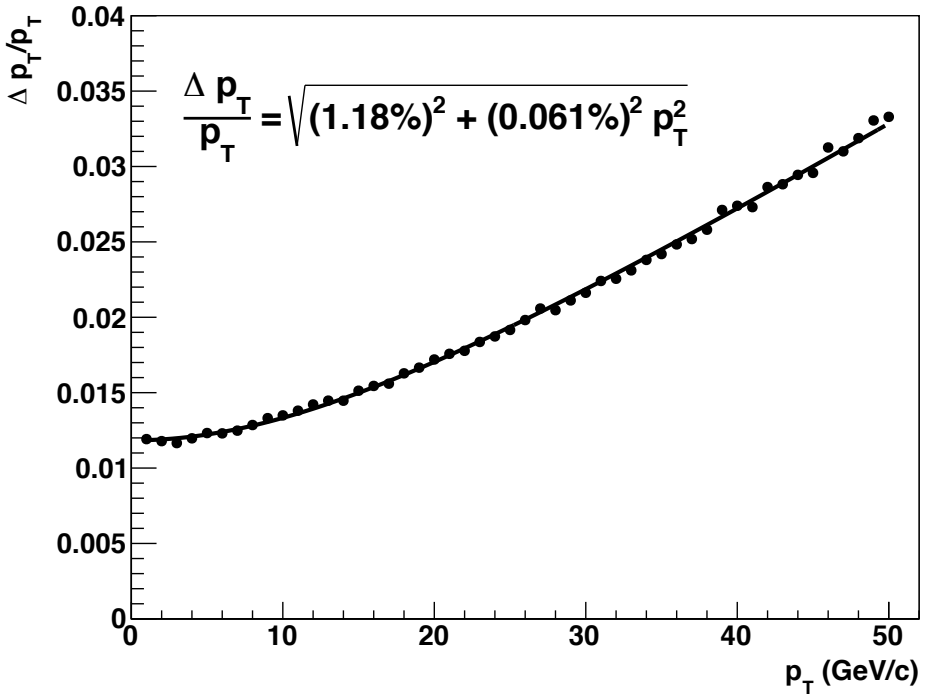
Development of 2x8 module





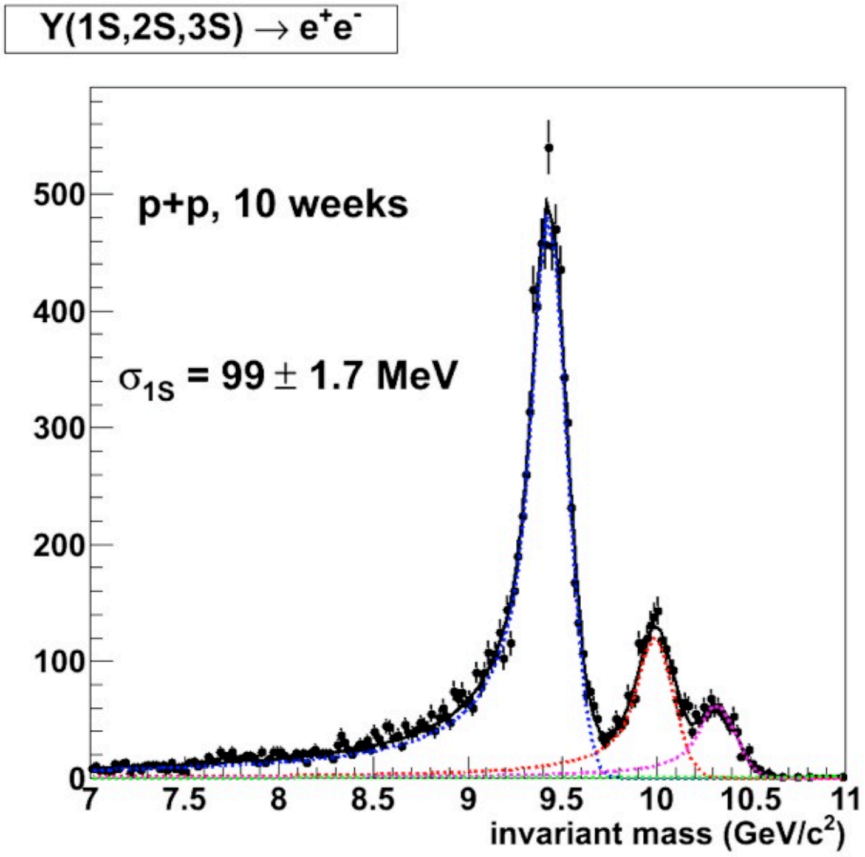
Momentum reconstruction





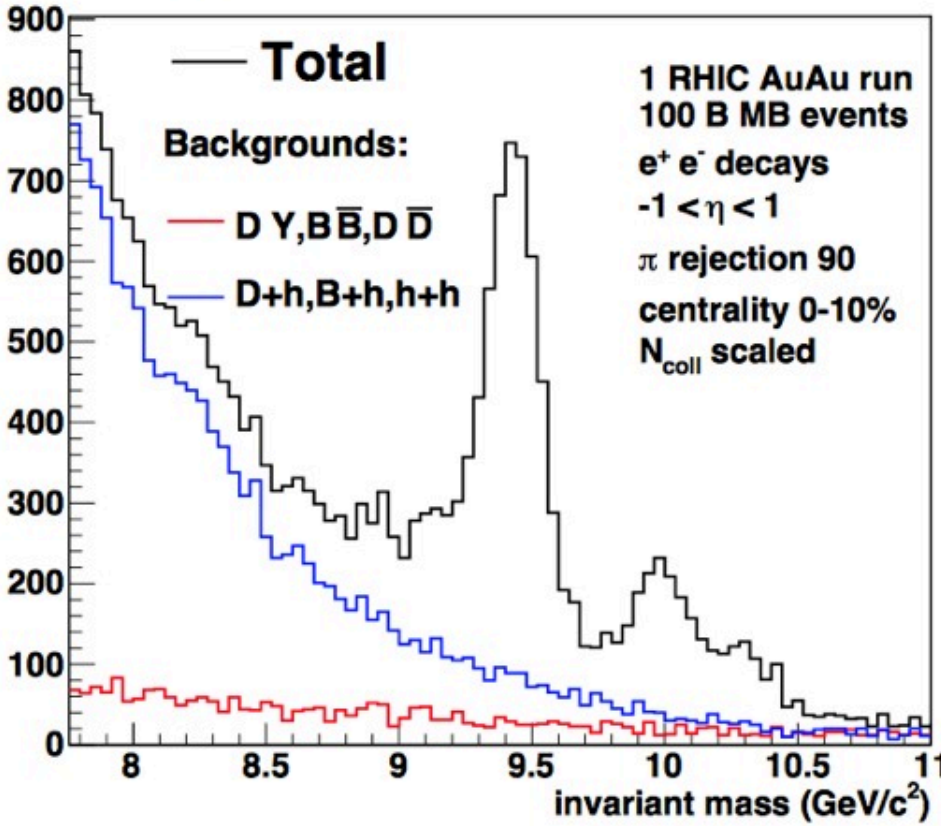
Two pixel layers
Two pairs of stereo strip layers
One outer strip layer
17 m^2 Si in 7 layers

Upsilon performance in p+p

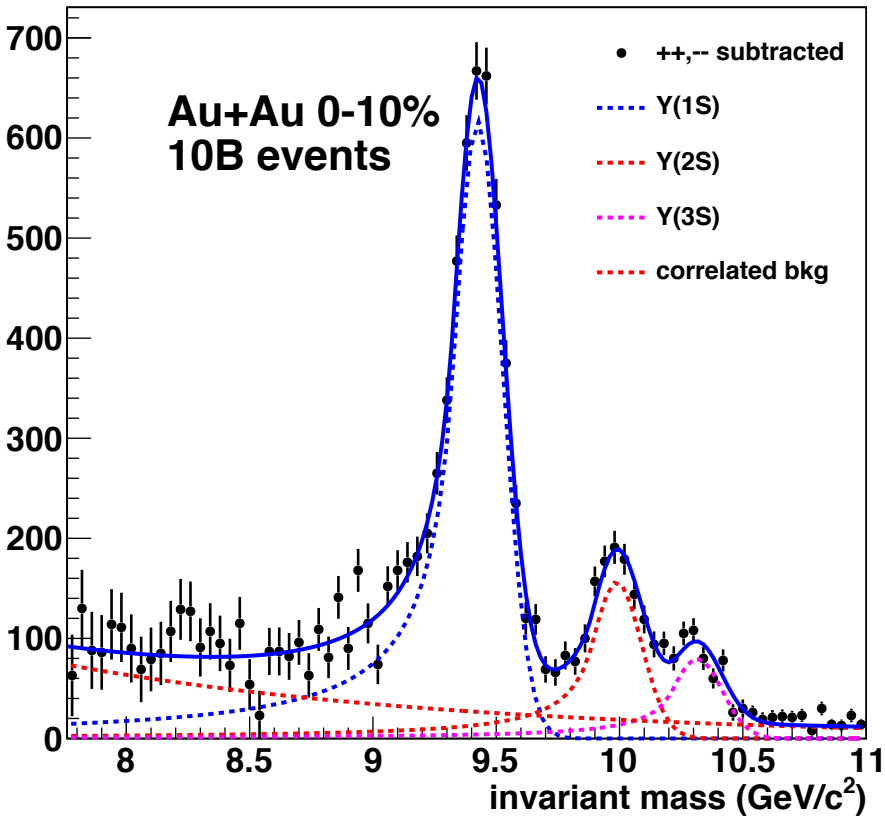


Upsilon performance in Au+Au

Υ(1S,2S,3S)

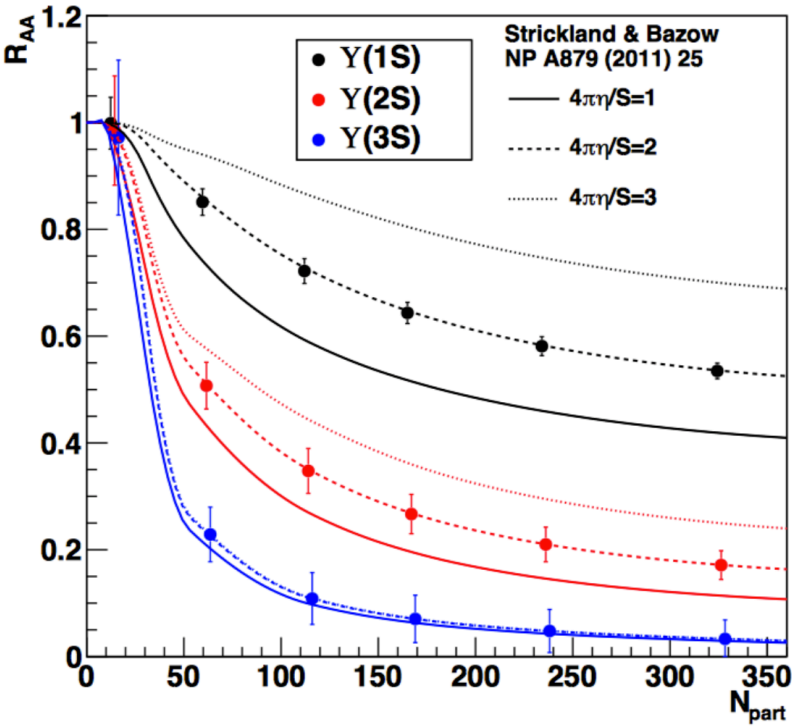


Υ(1S,2S,3S)

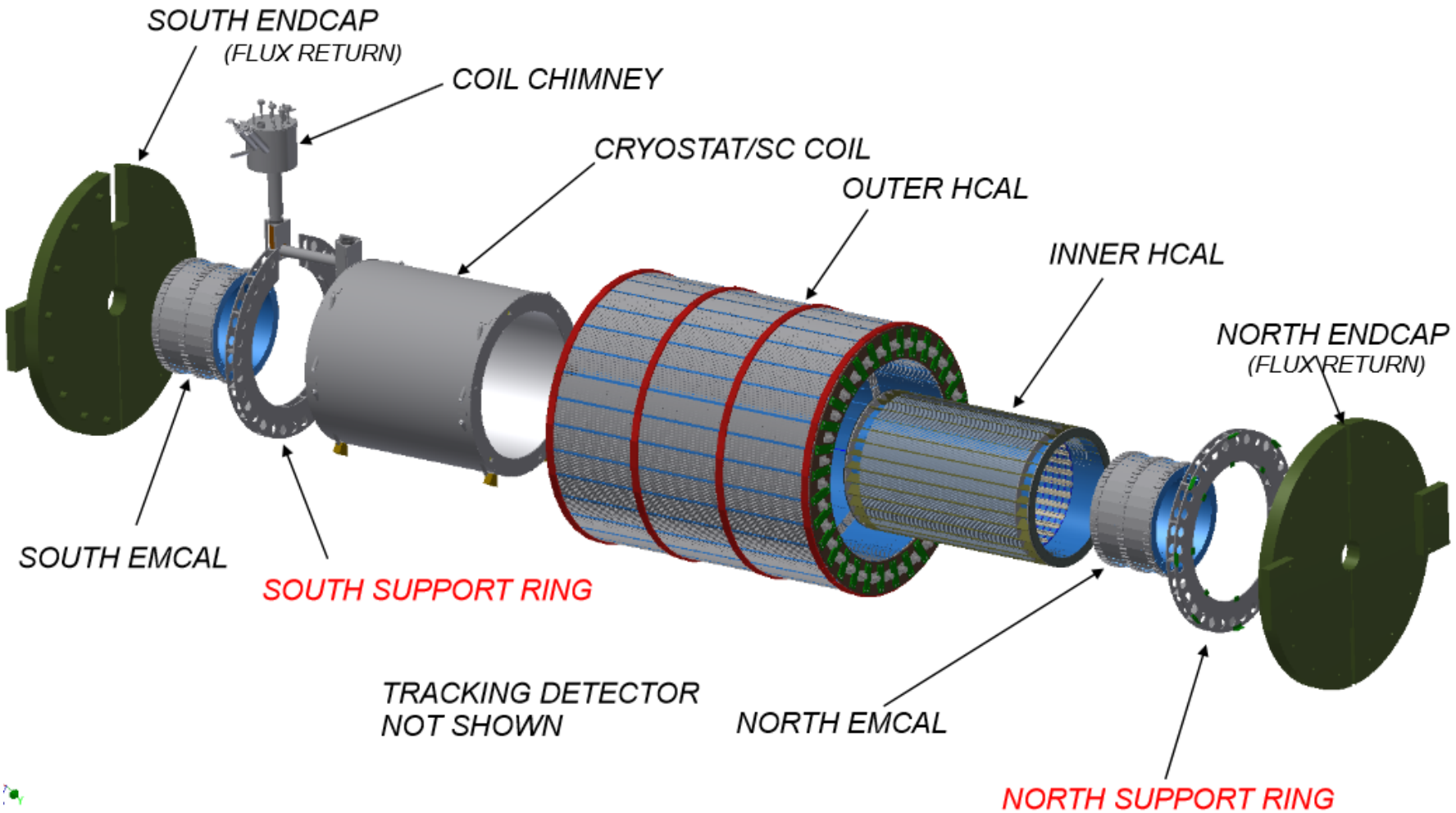


Nuclear modification projections for Upsilons

- With
  - 10 weeks p+p
  - 22 weeks Au+Au
- Yield and S/B scaled to match model suppression



Putting it all together



R&D, work in progress

- We have had one beam test of an early version of our calorimeter design in February 2014
- Second prototype planned for April 2016 for all three calorimeter sections
- Low power cold test of magnet being prepared
- Radiation damage tests of SiPM's
- Development of production techniques for the SPACAL
- Finite element analysis of structure
- New digitizers being developed at Nevis
- Exploration of tracking options

FTBF T-1044

Status and next steps

- DOE panels accepted science case at a review and followup (July 2014/ May 2015) without further recommendations
  - "The proponents should be congratulated on the excellent work they have done on expanding the Upgrade Proposal for sPHENIX since the first review. They have strengthened and expanded the physics case and included more detailed studies to demonstrate the detector capabilities. All the questions from the first review have been thoughtfully answered."
- sPHENIX is an integral part of the PHENIX and BNL plan after a final PHENIX run in 2016
- Design, simulation, project planning, R&D, prototyping all moving forward rapidly
- Berndt Mueller (BNL Associate Director) convened a workshop to form a new collaboration in June 2015: https://www.bnl.gov/lajudr2015/
- We are planning for
  - CD-1 in early FY2018
  - CD-2/3 and construction start late in FY2018